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TITLE:

WOUND THERAPY DEVICE

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1 This is a continuation application claiming priority to U.S. Patent Application
2 Serial No. 09/545,339 filed April 7, 2000 and any amendments thereof.

3 **BACKGROUND OF THE INVENTION**

4 **1.Field of The Invention**

5 The present invention relates to the healing of wounds and, more particularly, but
6 not by way of limitation, to an apparatus for closing wounds that is compact, self-
7 contained, and includes a disposable wound fluids canister and a porous pad, which is
8 biocompatible with the wound tissue to facilitate the healing of wounds, but does not
9 adhere to the healing tissue.

10 **2.Background Information**

11 Wound closure involves epithelial and subcutaneous tissue adjacent to the wound
12 migrating towards the center of the wound until it closes. Unfortunately, closure is
13 difficult with large wounds or wounds that have become infected. In such wounds, a
14 zone of stasis (i.e. an area in which localized swelling of tissue restricts the flow of blood
15 to the tissues) forms near the surface of the wound. Without sufficient blood flow, the
16 epithelial and subcutaneous tissues surrounding the wound not only receive diminished
17 oxygen and nutrients, but are also less able to successfully fight bacterial infection and,
18 thus are less able to close the wound naturally. Such wounds have presented difficulties
19 to medical personnel for many years.

20 The most common technique for closing open wounds has been the use of sutures
21 or staples. Although such mechanical closure techniques are widely practiced and often

1 effective, they suffer a major disadvantage by providing tension on the skin tissue
2 adjacent the wound. That is, the tensile force required to achieve closure using sutures or
3 staples causes very high localized stresses at the suture or staple insertion point. Such
4 stresses commonly result in the rupture of the tissue at those points, which can eventually
5 cause dehiscence in wounds, providing additional tissue loss.

6 Moreover, some wounds harden and inflame to such a degree due to infection that
7 closure by stapling or suturing is not feasible. Wounds not reparable by suturing or
8 stapling generally require prolonged hospitalization with its attendant high cost, and
9 major surgical procedures, such as grafts of surrounding tissues. Examples of wounds
10 not readily treatable with staples or sutures include large, deep, open wounds; decubitus
11 ulcers; ulcers resulting from chronic osteomyelitis; graft site wounds; and partial
12 thickness burns that subsequently develop into full thickness burns. The use of skin
13 grafts in these situations can result in the encapsulation of bacteria and other impurities.

14 The above problem is discussed in WO 93/09727 which proposes as a solution a
15 procedure for draining the wound by applying a continuous negative pressure to the
16 wound over an area sufficient to promote migration of epithelial and subcutaneous tissue
17 toward the wound. Although WO 93/09727 deals in some detail with the clinical
18 considerations of this kind of treatment, the apparatus described has certain practical
19 shortcomings.

20 One problem with the apparatus described in the above prior document is that no
21 means are disclosed for avoiding spread of infection from one patient to another or re-

1 infection of the patient being treated. The pad in the wound drainage device can be
2 modified with an antimicrobial agent, such as Neosporin, to limit the migration of
3 bacteria through the pad and into the vacuum tubes and canister while negative air flow is
4 engaged as well as into the patient when the air flow has been disengaged.

5 An objective is to have a pad that (a) is made from biocompatible material and (b)
6 has sufficiently small pore size that granulation tissue does not migrate into the pad.
7 Granulation tissue is a matrix of collagen, fibronectin and hyaluronic acid carrying
8 microphages, fibroblasts and neovasculature that aids in healing. This objective may be
9 accomplished by using a pad that (a) has a tissue compatible lubricious surface, (b) has a
10 growth factor impregnated surface, (c) has a molecular graft on the pad surface, and/or (d)
11 is antimicrobial.

12 The pad utilized in the wound drainage device can be formed by several different
13 means with the ultimate goal of providing a vacuum compatible portion and a healing
14 tissue compatible portion. It is known in the prior art that foam can be blown to form
15 porous materials; however, it is not disclosed in the prior art that foam can be blown into
16 a wound cavity to form a biocompatible porous pad which is both compatible with the
17 healing tissue and compatible with the vacuum and negative air flow as in the present
18 invention. It is known in the prior art that surgical dressings, such as teflon or rayon, are
19 useful because they are compatible with healing tissue, but it is not disclosed in the prior
20 art the use of porous surgical dressings in conjunction with a porous pad as in the present
21 invention. It is known in the prior art that biocompatible substances such as Hydromers

1 can be used as a coating material to increase lubricity and/or reduce pore size of pads;
2 however, the prior art does not disclose the use of such substances to coat pads as used in
3 the present invention. It is known in the prior art that antimicrobial agents can be used to
4 deter bacterial growth; however, the prior art does not disclose the use of such agents in
5 conjunction with the pad of the present invention.

6 **SUMMARY OF THE INVENTION**

7 It is a primary object of the present invention to provide a wound closure
8 apparatus that closes wounds without stressing the surrounding skin.

9 It is another object of the present invention to render technology like that
10 disclosed in WO 93/09727 in a convenient, compact and self-contained, efficient and
11 economically feasible system.

12 It is a further object of the present invention to provide a wound closure apparatus
13 that includes a removable and disposable wound fluids collection canister to protect the
14 wound closure apparatus from contamination.

15 It is still a further object of the present invention to provide a wound closure
16 apparatus which makes use of a porous pad with a smooth outer surface having pores of a
17 diameter of approximately 100 microns or smaller so as to prevent skin regrowth therein.

18 It is another object of the present invention to provide a porous pad which can be
19 used in conjunction with a wound closure apparatus which pad has a tissue compatible
20 lubricious surface, has a growth factor impregnated surface, has a molecular grafted
21 surface and/or is antimicrobial.

1 In accordance with the present invention, there is provided a therapeutic apparatus
2 for stimulating healing of wounds, said apparatus including a housing that contains a
3 vacuum pump and a chamber for holding a disposable wound drainage collection
4 cannister. The cannister preferably resides within the chamber and connects at an outlet
5 with the vacuum pump and at an inlet with a pad. The pad is of a porous, compliant
6 material which works well for distributing gas pressure in the wound environment and
7 which also complies with the negative air flow. The pad has a smooth outer surface that
8 has pores close enough together so that the healing tissue will not grow into the pad. The
9 pores on the outer surface of this pad less than one millimeter, normally in the
10 approximate upper range of 100 microns (or less) in diameter in areas where the pad is in
11 contact with the wound. The outer surface of the pad can consist of the outer portion of
12 the pad itself, a material adhered to the pad, or a material placed over the pad. The pad is
13 placed over the wound or pressed into the wound and adhesively secured thereto to create
14 a sealed environment at the wound. The pad is designed such that when the pad is
15 removed it does not disrupt the healing tissue. Thus, when the vacuum pump activates, it
16 evacuates air from the canister and thence the wound environment, resulting in the
17 application of negative pressure to the wound, which in turn tends to promote drainage of
18 fluids flowing from the wound into the canister. After the canister is filled, it is removed
19 from the chamber, disposed of, and replaced with another canister to continue therapy.

20 **BRIEF DESCRIPTION OF THE DRAWINGS**

21 Figure 1 is a perspective view depicting the vacuum pump unit of a wound closure

1 apparatus constructed according to the teachings of the present invention.

2 Figure 2 is a right side plan view depicting the vacuum pump unit of Figure 1.

3 Figure 2A is a detail view of the latch 26 portion of Figure 2, partially cutaway to
4 eliminate guide (or "key") 29 from the view and to show portions of latch 26 in sagital
5 cross section.

6 Figure 3 is a perspective view depicting a wound drainage collection canister for
7 use in conjunction with the vacuum pump unit of Figure 1.

8 Figure 4 is a rear plan view depicting the wound drainage collection canister of
9 Figure 3.

10 Figure 5 is a perspective view depicting the connection of a wound drainage
11 collection canister of Figure 3 to a wound coverage pad.

12 Figure 6 is a front plan view in partial cross section depicting the connection of
13 the wound drainage collection canister of Figure 3 within the housing of the vacuum
14 pump of Figure 1.

15 Figure 6A is a partial view of the apparatus shown in Figure 6 except the canister
16 is removed.

17 Figure 7 is a perspective view depicting the filter carrier of the wound drainage
18 collection canister.

19 Figure 8 is a top plan view depicting the filter cap of the wound drainage
20 collection canister.

21 Figure 9 is a schematic view depicting the control system for a wound closure

1 apparatus constructed according to the teachings of the present invention.

2 Figure 10 is a section through a wound showing the wound pad in place.

3 Figure 11 is a porous wound pad being dipped into a solution.

4 Figure 12 is a porous wound pad with varying porosity on two sides (with tube).

5 Figure 13 is a side of a porous wound pad being melted by a heat source.

6 Figure 14A is a cross section of chemical being sprayed into the wound.

7 Figure 14B is a cross section of chemical being sprayed into the wound (with
8 tube).

9 Figure 15 is a cross section of a wound where spraying of the chemical has been
10 completed (with tube).

11 Figure 16 is a cross section of a wound where the sprayed chemical has hardened
12 into the contours of the wound (with tube).

13 Figure 17 is a porous sock wrapped around the porous wound pad (with tube).

14 Figure 18 is a porous wound pad with a removable micropore layer (with tube).

15 **DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT**

16 As illustrated in Figures 1 and 2, front housing 11 and rear housing 12 connect
17 together using any suitable means such as screws and fasteners to provide wound closure
18 vacuum pump 10 with a small, compact, and easily portable carrying case. Consequently,
19 front housing 11 and rear housing 12 connect together to form handle 13 that permits easy
20 carrying of the wound closure apparatus 10. Except as may be otherwise evident from
21 this description, the carrying case of the vacuum pump 10 is substantially as described

1 and shown in WIPO Design No. DM/032185.

2 Front housing 11 includes power switch 15 that is movable between an on and off
3 position to permit user control of the delivery of power to the wound closure apparatus
4 10. Keypad 16 and liquid crystal display (LCD) 17 mount to front housing 11 to permit
5 the programming of the wound closure apparatus 10. Chamber 18 is defined by integrally
6 formed interior side walls 100 and 101, top wall 102, bottom wall 103 and rear wall 104.
7 Side wall 100 is dependently attached to the interior of the front housing 11 by standard
8 mounting hardware (not shown). The wound fluids collection canister 19, illustrated in
9 Figures 3-5, is received within chamber 18. Side walls 100 and 101 each include a key
10 29 and 30, respectively, that aid in the alignment of wound fluids collection canister 19
11 within chamber 18. Furthermore, front housing 11 includes latch 26 to secure the wound
12 fluids collection canister 19 within chamber 18.

13 Rear housing 12 includes arm 14 pivotally mounted to it within recess 110. An
14 identical arm pivotally mounts to the opposite side of rear housing 12 within an identical
15 recess. Arm 14 and its corresponding arm mounted on the opposite side of the rear
16 housing 12 pivot from within their recesses to a position where they support the wound
17 closure apparatus 10 at an angle. Arm 14 and its corresponding arm angularly support the
18 wound closure apparatus 10 to permit easier user access to keypad 16. Arm 14 and its
19 corresponding arm may also be used to permit hanging of apparatus 10 from a hospital
20 bed foot board.

21 Canister 19 has a shape as shown in Figures 3 to 6. As illustrated in Figures 3 to

1 6, canister 19 includes side walls 20 and 21, top wall 23, bottom wall 24, back wall 22
2 and front wall 25 that define the rectangular chamber for receiving blood, pus, and other
3 fluids emitted from a wound. Side walls 20 and 21 include key ways 27 and 31
4 respectively, that receive a respective one of keys 29 and 30 to provide easy alignment of
5 canister 19 within chamber 18. Furthermore, key way 27 includes recess 28 that receives
6 latch 26 to fasten canister 19 within chamber 18.

7 Front wall 25 of canister 19 includes raised portion 32 extending therefrom to
8 furnish a window that permits a user to determine the level of wound fluids within
9 canister 19. Accordingly, raised portion 32 is transparent so that the level of wound
10 fluids within canister 19 may be visually determined. Raised portion 32 includes side
11 walls 110 and 111, top wall 112, bottom wall 113, and front face 114 that define a
12 chamber which opens into the chamber defined by side walls 20 and 21, top wall 23,
13 bottom wall 24, back wall 22 and front wall 25 of canister 19. Front face 114 of raised
14 portion 32 includes graduations that demarcate the volume of wound fluid within canister
15 19. Additionally, side walls 110 and 111 of raised portion 32 include ridges that provide
16 a gripping surface for the user during the insertion and removal of canister 19 from
17 chamber 18.

18 Although raised portion 32 is transparent to permit the determination of the level
19 of wound fluids within canister 19, side walls 20 and 21, back wall 22, top wall 23,
20 bottom wall 24, and front wall 25 are opaque so that they are only translucent. As an
21 alternative, the portions of canister 19 surrounding filter 46 may also be transparent. This

1 enables a user to visually check for signs of contamination of filter 46. In this preferred
2 embodiment, side walls 20 and 21, back wall 22, top wall 23, bottom wall 24, front wall
3 25, and raised portion 32 of canister 19 are fabricated from a plastic material.

4 Canister 19 includes inlet 35 that is formed integrally with top wall 112 of raised
5 portion 32. Inlet 35 is cylindrical in shape and communicates with the interior of canister
6 19 to permit the transfer of wound fluids into canister 19. In this preferred embodiment,
7 inlet 35 is also fabricated from a plastic material.

8 In order to prevent liquids sucked into the canister 19 from splashing directly onto
9 cap 49, which mask the outlet 44, and to reduce foaming within the canister 19, inlet 35
10 has a blind inner end. Inlet 35 has a slot 35A so that drainage fluid is deflected
11 downwardly into the raised handle portion 32 of the canister 19. Handle portion 32 may
12 communicate with the main part of the canister 19 through one or more holes in wall 25.
13 It is desirable to avoid foaming because this can give a false reading when a capacitance
14 sensing device is used to sense when the canister 19 is filled. An anti-foaming material,
15 e.g. a silicone, may be added to the canister 19, e.g. by coating the interior walls. It may
16 also be advantageous to include a gel-forming substance, e.g. a polyacrylamide of
17 modified starch in order to immobilize the drainage fluid. This is particularly useful if
18 the apparatus is likely to be tilted.

19 Wound fluids (i.e. drainage) are communicated through inlet 35 into canister 19
20 via pad 36 and hoses 37 and 38. In this preferred embodiment, the portion of the pad 36
21 next to the vacuum tube 37 (i.e. inner portion or surface) is fabricated from an open cell

1 polyurethane or polyether foam. The outer surface of the pad 36 in contact with the
2 wound cavity 216 can consist of the same material as the inner portion or surface next to
3 the vacuum tube 37 where the size of the pores is 100 microns or less. Hose 37 is
4 inserted within pad 36 by making an incision in pad 36 and inserting the end of hose 37.
5 Hose 37 can then be secured within pad 36 using any suitable means such as an adhesive
6 or a flange. Preferably, the porous pad 36 has an elongated hole 300 (See Fig. 11) for the
7 drainage tube 37 which is an interference fit with the tube 37. The hoses 37 and 38 are
8 preferably made from medical grade PVC tube. Hose 38 mounts within inlet 35 using
9 any suitable means such as adhesive or welding. Hoses 37 and 38 include luer lock
10 connectors 39 and 40, respectively, (or the equivalent, such as any known quick
11 disconnect type coupling) that attach together to permit communication between hoses 37
12 and 38. Furthermore, hoses 37 and 38 include pinch clamps 41 and 42, respectively, that
13 are capable of sealing their respective hose 37 or 38 to prevent the flow of wound fluids.
14 The porous pad 36 is preferably packaged in a sterile container together with its connector
15 and clamp. When packaged, the clamps will be in their open condition.

16 The communication of wound fluids into canister 19 requires the securing of pad
17 36 over a wound. Pad 36 is secured over a wound using cover 43 which is fabricated
18 from a plastic material and includes an adhesive on one side that sticks to human skin.
19 Wound cover 43 is conveniently a surgical drape material comprising a sheet of
20 elastomeric material coated peripherally or overall with a pressure-sensitive adhesive,
21 such as an acrylic adhesive. The elastomeric or rubbery nature of the wound cover 43 is

1 important because it accommodates changes in pressure in the wound area during
2 intermittent operation of the vacuum pump 84. The wound cover 43 is preferably a
3 polyurethane film with a removable backing sheet, i.e. of polythene to protect the
4 adhesive surface.

5 A high degree of reticulation in the inner portion or surface of the porous pad 36
6 next to the vacuum tube 37 is desirable to achieve good permeability when the pad 36 is
7 under suction. The outer surface of the pad 36 next to the wound, however, is smooth
8 and contains pores of approximately 100 microns in diameter to allow for vacuum air
9 flow through the pad 36 while preventing the healing tissue from cross linking with the
10 pad 36. While the upper range of pore size is not exactly known, it is between 100
11 microns and 1000 microns (one millimeter). The lower end of the pore size is simply
12 large enough to allow air and fluids to flow therethrough which could be as small as one
13 micron.

14 There are several different ways to prepare a pad 36 for use with the wound
15 drainage apparatus 10 which contains an outer surface with the preferred specifications.
16 One way is to make a porous pad 36 out of a material which consists entirely of
17 micropores (not shown) with a diameter of approximately 100 microns or less, or blow
18 the pad 36 in such a way that the portion to be inserted into the wound cavity contains the
19 micropores of a diameter of approximately 100 microns or less as will be subsequently
20 described. A micropore is an opening in the pad 36 of approximately 100 microns or
21 less.

1 Referring to Figures 11 and 12, a second way to create the pad 36 is to dip the
2 portion of the pad 36 which is to be placed inside the wound in a liquid coating material
3 201 which dries into the pad 36 acting as a bulking agent thereby reducing the diameter of
4 the pad pores 205 to approximately 100 microns or less. This effectively creates a
5 smooth outer surface with a pore size of approximately 100 microns or less, hereinafter
6 called micropores 207, to be placed in the wound cavity 216. An inner surface can have
7 pores 205 of a size of greater than 100 microns which have a greater vacuum compatibility
8 with the vacuum tube 37.

9 In Figure 11, a porous wound pad being dipped into a solution 201 is shown.
10 Figure 11 shows a porous wound pad 36, with top 203, bottom 204, and side 206. The
11 pores 205 of the porous wound pad 36 are a vacuum compatible size. A vacuum tube 37
12 is shown in the side 206 of the porous wound pad 36. The pad 36 is being dipped to
13 approximately 1 millimeter into a liquid coating material 201, such as a liquid hydrophilic
14 foam solution, held in a flat tray 202, which when hardened acts as a bulking agent to
15 form a smooth micropore layer 211 with micropores 207 of a diameter of approximately
16 100 microns or less. This allows for the flow of negative air pressure and fluids through
17 the pad 36 without compromising the healing tissue surface. The coating of the pad 36
18 can occur directly before insertion into the wound cavity 216, allowing enough time for
19 drying, or the pad 36 can be coated during manufacturing. Furthermore, for certain types
20 of wounds it may be necessary to mix an antimicrobial agent such as Neosporin with the
21 liquid coating material 201 so as to create a modified pad surface which is difficult for

1 bacteria to stick to thus preventing bacterial migration through the pad 36. The addition
2 of the coating to the pad 36 does not hamper the ability to trim the pad 36 to conform to
3 the wound cavity 216.

4 Figure 12 shows a cross section of a porous wound pad 36 with varying porosity
5 on one surface (with tube). This varying porosity can result from the porous pad 36, with
6 top 203, bottom 204 and side 206, being dipped in the liquid coating material 201 as
7 described in Figure 11. This pad 36 contains an upper pore layer 212 with vacuum
8 compatible pores 205 and a smooth micropore layer 211 with healing compatible pores
9 207 which have a diameter of approximately 100 microns or less. By having a size of
10 approximately 100 microns or less, tissue cannot grow into the micropore layer 211.
11 Again the liquid coating material 201 (a) can be modified with an antimicrobial agent
12 such as Neosporin to deter bacterial migration through the pad 36, or (b) forms a tissue
13 compatible lubricious surface that is growth factor impregnated or is a molecular graft.

14 Referring to Figure 13, another way of creating the optimum outer pad surface is
15 to take a porous pad 36 with pores 205 that may have a diameter greater than 100 microns
16 and heat that pad 36 on the side to be placed inside the wound cavity 216 with a heat
17 source 208 so as to shrink or melt the pore size to a diameter of approximately 100
18 microns or less while maintaining a smooth texture. In Figure 13, a side of a porous
19 wound pad being melted by a heat source is shown. The pad 36, with top 203, bottom
20 204, and side 206 and containing pores 205 of vacuum compatible pore size, is shown on
21 a hot plate 208. This hot plate 208 has a standard current adapter 209 and plug 210.

1 While a hot plate 208 was used in this illustration, any heat source could be used. The
2 heat source 208 was simply necessary to melt the surface of the pad 36 partially so as to
3 create a smooth micropore layer 211 with healing compatible micropores 207 of
4 approximately 100 microns or less.

5 Referring to Figures 17 and 18, the porous pad 36 can be made with a smooth
6 outer surface of approximately 100 microns or less by taking a pad 36 with vacuum
7 compatible pores 205 and placing the pad 36 within a porous sock 213 which is smooth
8 and contains pores 207 with a diameter of approximately 100 microns or less. The sock-
9 covered pad 36 is then placed inside the wound cavity (not shown in this Figure). Figure
10 17 shows a porous wound pad 36 situated within a porous sock 213. The pad 36, with
11 top 203, bottom 204, and side 206, has vacuum compatible pores 205 and a vacuum tube
12 37 for use in extending the negative air pressure through the pad 36. The porous sock
13 213 contains healing compatible pores 207 of a diameter of approximately 100 microns or
14 less and acts as a covering being placed over the porous wound pad 36 before insertion
15 into the wound cavity 216. If any trimming of the pad 36 is needed it can be done before
16 the pad 36 is placed in the sock 213 before insertion into the wound cavity 216.

17 Referring specifically to Figure 18, a variation of the technique demonstrated in
18 Figure 17 would be to affix a smooth porous membrane 219 only to the face of the pad 36
19 that is to be placed into the wound cavity 216. This membrane 219 contains pores of a
20 diameter of approximately 100 microns or less. The porous sock 213 or membrane 219
21 may be composed of TEFLON, rayon, or a similar material. Knit rayon film is often used

1 for conventional dressings to try to accelerate the growth of granulation tissue. The
2 membrane 219 may form a tissue compatible lubricious surface that is growth factor
3 impregnated and antimicrobial. In Figure 18, a porous wound pad 36 with a removable
4 membrane 219 is shown. The pad 36, with top 203, bottom 204, and side 206 and
5 vacuum compatible pores 205, contains a vacuum tube 37 for use in extending the
6 negative air pressure through the pad 36 for aspiration of the wound cavity 216. The
7 removable membrane material 219, such as teflon or rayon, contains healing compatible
8 micropores 207 of a diameter of 100 microns or less. This membrane material 219 can be
9 placed around the portion of the pad 36 which is to go into the wound cavity 216. The
10 membrane 219 can be held in place on the pad 36 by any biocompatible means such as an
11 adhesive.

12 Referring to Figures 14 through 16, another way in which the pad 36 is made is by
13 spraying a nontoxic chemical substance 215 directly into the wound cavity 216. The
14 chemical substance 215 hardens into the shape of the wound cavity 216 when placed
15 directly into the wound 216. This forms a pad 36 such that the surface of the pad 36 next
16 to the healing tissue is smooth and has pores of a diameter of approximately 100 microns
17 or less. A chemical substance (not shown) can also be sprayed in a sterile environment
18 before insertion into the wound cavity 216. When the pad 36 is formed on an external
19 sterile surface it is allowed to harden slightly into a foam like substance and then pressed
20 into the wound cavity 216 so as to conform to the wound. The chemical substances used
21 in these circumstances are sprayed so as to make a pad 36 with a smooth outer surface

1 containing pores with a diameter of approximately 100 microns or less.

2 Figure 14A shows a cross section of chemical being sprayed into a wound. A
3 nontoxic chemical substance 215 is sprayed from the spray nozzle 218 of a container (not
4 shown). The chemical substance 215 is under pressure such that when it is sprayed into
5 the wound cavity 216 of the body 214 the gas is expelled from the chemical substance
6 215 which allows the chemical substance 215 to expand from a liquid phase to a solid
7 porous phase which conforms to the shape of the wound cavity 216 (See Figure 15 where
8 the solidification of the pad 36 is shown with a wound cover 43 placed over the pad 36
9 and tube 37 assembly.). The vacuum tube 37 should be placed in the cavity 216 during
10 the spraying of the chemical substance 215 before solidification occurs (See Figure 14B).

11 This porous pad 36 which is formed (See Figure 16) is equally vacuum compatible next
12 to the vacuum tube 37 as well as compatible with the healing tissue containing a smooth
13 surface and only micropores 207 of approximately 100 microns or less in diameter in
14 contact with the wound cavity 216.

15 The type of pad 36 can vary based on the type of wound involved. In addition, the
16 type of wound may dictate that an antimicrobial agent, such as Neosporin, be used in the
17 pad 36 entirely or on the surface which is in contact with the wound so as to give a topical
18 antimicrobial effect.

19 In use, the porous pad 36 is cut to a size which corresponds closely to the edge of
20 the wound with the objective of packing the pad 36 into the wound cavity 216 so that it
21 contacts the surface of the cavity 216, rather than bridging the cavity 216. As depicted in

1 Figure 10, the cavity 216 may be extensive and there may be little or no tissue coverage to
2 the bone 212. This is illustrated diagrammatically in Figure 10. Figure 10 is a cross-
3 section through a wound showing the porous pad 36 packed in the wound cavity 216. It
4 is important that the pad 36 should be firmly packed into the recesses of the wound cavity
5 216. Drainage tube 37 terminates within the center of the porous pad 36. Surgical drape
6 43 extends over the porous pad 36 and is adhered to intact skin around the periphery of
7 the wound. Drape 43 is also firmly adhered around the tube 37 to prevent leakage of air.
8 A wound cover 43 is then adhered to the surrounding skin and around the drainage tube
9 37 to provide an air-tight seal around the wound.

10 As illustrated in Figures 2, 4 and 6, canister 19 includes outlet 44 that mounts over
11 port 45 to permit wound closure apparatus 10 to draw wound fluids into canister 19.
12 Outlet 44 is cylindrically shaped and formed as an integral part of back wall 22 by outer
13 wall 33 and inner wall 50 which are interconnected by end wall 34. Passageway 52,
14 defined in part by interior wall 50 and in part by filter cap 49, provides the actual conduit
15 for outlet 44 between the interior and exterior of canister 19. The placement of canister
16 19 within recess 18 such that outlet 44 resides over port 45 couples canister 19 to a
17 vacuum pump 84. The vacuum pump 84 removes air from canister 19 to create a vacuum
18 pressure within canister 19. That vacuum pressure is then transmitted to a wound site
19 through hoses 37 and 38, thereby not only enabling therapeutic use of system 10, but also
20 tending to promote wound drainage. Any wound drainage fluid is then drawn through
21 pad 36 and hoses 37 and 38 into canister 19.

1 Outlet 44 resides near top wall 23 of canister 19 to ensure efficient operation of
2 the vacuum pump 84. That is, the vacuum pump 84 removes the most air from canister
3 19 when the air does not have to first bubble through wound fluids contained in canister
4 19. Consequently, with outlet 44 positioned near the top of canister 19, the vacuum pump
5 84 removes air directly from canister 19, and it is only during the final filling of canister
6 19 that air must bubble through wound fluids. Preferably, as described below, the
7 apparatus includes detecting and warning means which operates before the level of
8 drainage fluid reaches either the inlet or outlet tube so that a fresh canister 19 can be
9 installed.

10 In removing fluids from a wound utilizing wound closure apparatus 10, a major
11 safety concern is preventing wound fluids from contaminating the vacuum pump 84.
12 Accordingly, filter 46 mounts over outlet 44 utilizing filter carrier 48 and filter cap 49 to
13 block the flow of wound fluids to outlet 44 so that wound fluids remain within canister 19
14 and do not flow into the vacuum pump 84. In this preferred embodiment, filter 46 is a
15 0.2 micron hydrophobic membrane filter providing a bacterial barrier, although other
16 filters may be substituted as appropriate.

17 As illustrated in Figure 7, filter carrier 48 includes face 53 formed integrally with
18 lip 54. Face 53 includes groove 56 formed therein, while lip 54 supports brace 55 in its
19 interior. Filter 46 fits within groove 56 of face 53 and is supported within filter carrier 48
20 by brace 55 of lip 54. An O ring 53A is fitted in peripheral recess of filter carrier 48 to
21 accommodate manufacturing tolerances and ensure a fluid tight seal with filter cap 49.

1 As illustrated in Figures 6 and 8, filter cap 49 includes cylindrical portions 57 and
2 58, which are formed integrally (with annulus 57' spanning there between), to hold filter
3 carrier 48 within passageway 52 of outlet 44. To mount filter 46 over passageway 52,
4 filter 46 is first placed within filter carrier 48 as described above. Filter carrier 48 is then
5 positioned within filter cap 49 such that face 53 abuts annulus 57' of filter cap 49 and lip
6 54 of filter carrier 48 resides within annular lip 50' of outlet 44. Accordingly, when
7 cylindrical portion 57 of filter cap 49 mounts over outlet 44, the front face 53 of filter
8 carrier 48 and the outer edges of filter 46 abut annulus 57' to secure filter 46 within
9 passageway 52. Filter cap 49 attaches to outlet 44 using any suitable means such as an
10 adhesive or welding. Filter cap 49 is completely sealed except for aperture 51 positioned
11 on top of filter cap 49. Aperture 51 communicates with port 45 via passageway 52 of
12 outlet 44 to permit the vacuum pump 84 to draw air from the interior of canister 19.

13 As illustrated in Figures 2 and 6, port 45 includes O-ring 59 mounted thereabout
14 to provide a fluid tight seal between port 45 and inner wall 50 of outlet 44. Port 45
15 mounts through rear wall 104 of chamber 18 using any suitable means such as nuts 60
16 and 61. Furthermore, line 62 attaches to the rear of port 45 using any suitable means such
17 as a clamp to couple port 45 to the vacuum pump 84.

18 Switch 63 protrudes through rear wall 104 of chamber 18 to produce a signal
19 indicating when canister 19 properly and securely resides within chamber 18. In this
20 preferred embodiment, switch 63 is a normally open push button switch that mounts on
21 rear wall 104 of chamber 18 using any suitable means such as a bracket. When canister

1 19 is properly positioned within chamber 18, its rear wall 22 presses the head of switch
2 63, closing switch 63 so that it provides a signal indicating that canister 19 properly
3 resides within chamber 18.

4 Fill sensor 64 resides adjacent side wall 101, exterior to chamber 18. Fill sensor
5 64 provides a signal that indicates when canister 19 is filled with wound debris. In this
6 preferred embodiment, fill sensor 64 is a capacitive sensor that mounts on side wall 101
7 of chamber 18 using any suitable means such as a bracket or appropriate adhesive
8 material. Fill sensor 64 has a sensing profile 64A which determines the point at which
9 the capacitance measurement is made. When wound fluids have reached the level within
10 canister 19 which corresponds to the location of the sensing profile 64A, the capacitance
11 within canister 19 as 'seen' by fill sensor 64 changes, resulting in fill sensor 64 outputting
12 a signal indicating that canister 19 is filled with wound fluids to the level at which the
13 sensing profile is located. The position of this sensing profile behind wall 101 can be
14 changed (see Figures 6A) to provide an optimum balance of space and volume utility.

15 As illustrated in Figure 2A, latch 26 generally comprises latch pin 65, handle 66,
16 latch guide sleeve 68A and spring 67. Latch pin 65 comprises a proximal end 65A and
17 distal end 65B. Latch guide sleeve 68A abuts the inner surface of front housing 11 and is
18 held securely in place from the outer side of front housing 11 by nut 68B. Handle 66
19 screws onto the proximal end 65A of latch pin 65 and is locked in position by nut 69A.
20 In the preferred embodiment, cover 68 over nuts 69A and 68B provides a surface against
21 which handle 66 abuts, thus preventing end 65B from excessively entering chamber 18 as

1 will be understood further herein. Cover 68 also provides aesthetic enclosure of nuts 69A
2 and 68B. Dependent attachment of side wall 100 (chamber 18), as described herein
3 above, is such that side wall 100 abuts latch guide sleeve 68A on the side distal front
4 housing 11. Further, this arrangement causes distal end 65B of latch pin 65 to project
5 into chamber 18 under the force of spring 67 (shown partially cut away). Spring 67
6 resides circumferentially about latch pin 65 within an axial bore of latch pin guide 68A.
7 Spring 67 exerts force between distal end 65B of latch pin 65 and an annulus within the
8 axial bore of latch pin guide 68A. A transverse slot in the distal end of latch pin guide
9 68A receives end 65B of latch pin 65, providing rotational alignment of end 65B and
10 further recess for end 65B when a user "pulls" handle 66 in an axial direction.

11 Latch 26 operates to ensure canister 19 remains secured within chamber 18. End
12 65B of latch 26 terminates in a point that protrudes through key 29 into chamber 18.
13 During the placing of canister 19 within chamber 18, key way 27 of canister 19 forces the
14 point 65B of the latch pin within key 29. However, once canister 19 has been properly
15 positioned within chamber 18, recess 28 resides below latch pin end 65B so that spring 67
16 biases the point 65B of latch pin 65 into recess 28 to prevent the removal of canister 19
17 from chamber 18. The removal of canister 19 from chamber 18 is accomplished by
18 grasping handle 66 and pulling the point 65B of latch pin 65 from recess 28. With the
19 point of latch pin 65 no longer within recess 28, canister 19 may be pulled from chamber
20 18 using its raised portion 32.

21 As illustrated in Figure 9, wound closure apparatus 10 preferably plugs into a

1 standard 115/120 VAC power source (e.g. an outlet) to supply power to control system
2 70. Alternative embodiments (not shown, although similar) are readily adapted for 220
3 VAC power by changing the power cord and appropriately rewiring the taps of the
4 transformer within DC power supply 71, as is readily known in the art. The application
5 of power to control system 70 is regulated by power switch 15 which is a standard push
6 button on/off switch. With power switch 15 depressed, DC power supply 71 receives the
7 115/120 VAC signal and converts it into a 12 VDC signal for use by fan 74 and vacuum
8 pump 84. A conventional voltage regulator 96 steps down the voltage to +5V for use by
9 each of the other DC components 16, 17, 63, 64, 72, and 75. Voltage regulator 96
10 connects to keypad 16, LCD 17, switch 63, fill sensor 64, microcontroller 72, transducer
11 75, and tilt sensor 82 to supply each of them with the +5V DC signal. Microcontroller 72
12 links to solid state relays (MOSFETs) 97 and 98 for controlling the provision of the 12
13 VDC power supply to fan 74 and pump motor 83, respectively.

14 As illustrated in Figure 1, once power switch 15 is depressed, a user employs
15 keypad 16 and LCD 17 to select the operating parameters for wound closure apparatus 10.
16 Wound closure apparatus 10 stores the previously selected operating parameters so that
17 upon power initialization, LCD 17 displays the phrase "NEW PATIENT" with the word
18 "NO" over arrow button 76, and the word "YES" over arrow button 77. If the user presses
19 arrow button 76 to answer no, wound closure apparatus 10 will operate at the previously
20 selected parameters. After answer no, the user pressures on/off button 78 to begin
21 operation of wound closure apparatus 10.

1 Conversely, if the user presses arrow button 77 to indicate a new patient, wound
2 closure apparatus 10 will operate either under default values or allow the user to select the
3 operating parameters. To operate under default parameters, the user presses on/off button
4 78 after pressing arrow button 77. However, to select his or her own values, the user
5 presses option button 79 after pressing arrow button 77.

6 Upon the pressing of options button 79, LCD 17 displays a bar graph representing
7 the spectrum of available vacuum pump pressures and a numerical representation of the
8 vacuum pump pressure presently displayed by the bar graph. The user changes vacuum
9 pump pressure using arrow buttons 76 and 77. The pressing of arrow button 76 reduces
10 vacuum pump pressure, while the pressing of arrow button 77 increases vacuum pump
11 pressure. After selecting the desired vacuum pump pressure, the user presses option
12 button 79 to save the selected vacuum pump pressure.

13 Once the selected vacuum pump pressure has been saved, LCD 17 displays the
14 pump operation times available to the user. The user may program wound closure
15 apparatus 10 to pump either continuously or intermittently. Thus, LCD 17 displays the
16 word "CONTINUOUS" over arrow button 76b and "INTERMITTENT" over arrow
17 button 77. The user selects continuous operation by pressing arrow button 76 followed
18 by on/off button 78 to activate the vacuum pump 84. In its continuous mode, wound
19 closure apparatus 10 runs its vacuum pump 84 continuously until on/off button 78 is
20 pressed again.

21 If the user presses arrow button 77 to select intermittent operation, LCD 17

1 displays a bar graph representing the minimum and maximum on times for the vacuum
2 pump 84. LCD 17 also displays the phase "ON TIME" and the numerical value presently
3 displayed by the bar graph. A user decreases the on time of the vacuum pump 84 by
4 pressing arrow button 76 and increases the on time of the vacuum pump 84 by pressing
5 arrow button 77. After selecting the desired on time, the user presses options button 79 to
6 save the selected on time value.

7 LCD 17 then displays a second bar graph representing the off time for the vacuum
8 pump 84 with the phrase "OFF TIME" and the numerical value presently depicted by the
9 bar graph. Again, arrow buttons 76 and 77 are pressed to increase or decrease,
10 respectively, the off time for the vacuum pump 84. After selecting the off time, the user
11 presses options button 79 followed by on/off button 78 to operate wound closure
12 apparatus 10 using the selected parameters.

13 Keypad 16 includes setting button 80 to permit the user to sequentially display the
14 currently selected operating parameters of wound closure apparatus 10. Keypad 16
15 further includes delay button 81 to permit the user to deactivate an alarm sounded in
16 response to an improper operating condition of wound closure apparatus 10. Delay
17 button 81 provides the user with the ability to silence alarms so that the alarm will not
18 have to be listened to during the correction of the problem.

19 Any new alarm conditions occurring within the fifteen minute period ("delay
20 period") after the pressing of delay button 81 will not be indicated by an audible alarm.
21 However, the pump will still be deactivated when appropriate, even during the delay

1 period.

2 Again referring to Figure 9, microcontroller 72 is a multi-port microprocessor
3 with a ten-bit analog to digital ("A/D") converter having associated memory that stores
4 the program directing microcontroller 72 during its controls of wound closure apparatus
5 10. After receiving and storing the user selected operational parameters and receiving an
6 on signal due to the pressing of on/off button 78, microcontroller 72 activates pump
7 motor 83 which, in turn, drives vacuum pump 84 to begin the removal of air from canister
8 19.

9 As vacuum pump 84 operates, it draws air from within canister 19, into line 62 via
10 outlet 44 of canister 19 and port 45. Line 62 connects to filter 85 and transducer 75 via
11 T-junction 91. Filter 85 is similar to filter 46 and thus ensures no wound fluids
12 contaminate vacuum pump 84. Filter 85 communicates with pump 84 via T-junction 88
13 and one arm of the latter is connected to bleed valve 86. Bleed valve 86 communicates
14 with the atmosphere to release pressure developed within line 62 by vacuum pump 84
15 after microcontroller 72 deactivates vacuum pump 84. Bleed valve 86 is sufficiently
16 small to ensure that it generally does not affect the vacuum pressure levels achieved by
17 vacuum pump 84 as it evacuates air from canister 19, except to prevent
18 overpressurization beyond 250 mm Hg and to prevent erratic operation of the vacuum
19 pump 84 at very low pressure settings.

20 In the preferred embodiment, an orifice of 0.5 mm diameter is especially preferred
21 for bleed valve 86. Valve 86 or the equivalent is particularly important for enabling

1 intermittent application of negative pressure, as the orifice 86 allows for gradual release
2 of the negative pressure (over a period of about fifteen seconds) when the pump motor 83
3 is de-actuated. Bleed valve 86 is positioned outside housing 11 to facilitate un-clogging
4 of aperture 86 in the event of a blockage. An aperture is provided in bleed valve 86,
5 which is machined from stainless steel. Flow control orifices would be alternatives.

6 Line 62 also includes T-connector 91 to connect it with line 92. Line 92 is
7 connected to tank 94 which acts as a damper to pressure changes in line 62. This
8 dampening effect, facilitated by restrictor 89 in line 93 between transducer 75 and T-
9 junction 91, causes the pressure measured by transducer 75 to be an accurate indication of
10 actual wound site pressure. Transducer 75 communicates with line 62 via line 93 to
11 measure tank 94 pressure and produce an electrical signal representative of that pressure.
12 Transducer 75 outputs its pressure signal to microcontroller 72.

13 Microcontroller 72 utilizes the pressure signal to control the speed of pump motor
14 83. As previously described, the user selects either a default vacuum pump pressure or a
15 desired vacuum pump pressure for the operation of wound closure apparatus 10. After
16 receiving the wound pressure signal from transducer 75, microcontroller 72 compares the
17 wound pressure with the user selected pressure. If the wound pressure is higher than the
18 user selected vacuum pump pressure, microcontroller 72 reduces pump motor speed to
19 decrease vacuum pump pressure and thus the pressure at the wound. Conversely, if the
20 wound pressure is less than the user selected vacuum pump pressure, microcontroller 72
21 increases the speed of pump motor 83 resulting in an increase in the vacuum pressure

1 applied at the wound.

2 Microcontroller 72 controls pump motor 83 by varying the amount of voltage
3 received by pump motor 83. That is, microcontroller 72 receives the 12 VDC signal from
4 DC power supply 71 and outputs a voltage between 0 and 12 VDC to pump motor 83 to
5 control its speed in accordance with the user selected vacuum pump pressure value.
6 Accordingly, microcontroller 72 employs feedback to ensure that the wound experiences
7 the user selected vacuum pump pressure. If the target pressure is not reached after a
8 period of five minutes, microcontroller 72 deactivates motor 83 and sounds the audible
9 alarm. Additionally, the feedback signal prevents maximum vacuum pump pressure from
10 being exceeded. If the wound pressure measured by transducer 75 exceeds a maximum
11 safe vacuum pump pressure microcontroller 72 deactivates pump motor 83 and activates
12 alarm 95 to signal a malfunction.

13 Wound closure apparatus 10 includes fan 74 to cool pump motor 83 and printed
14 circuit ("PC") board 200 during the operation of the wound closure apparatus 10. In the
15 preferred embodiment, microcontroller 72 controls fan 74 to always operate while power
16 is being supplied. In alternative embodiments, however, microcontroller 72 controls fan
17 74 to operate only in relation to motor 83, because it is only necessary for fan 74 to
18 operate if motor 83 is also operating. In such alternative, as long as pump motor 83
19 operates, microcontroller 72 runs fan 74. However, when microcontroller 72 deactivates
20 pump motor 83 it also deactivates fan 74.

21 Control system 70 includes fill sensor 64 to provide a signal to microcontroller 72

1 that indicates when canister 19 is completely filled with wound fluids. After receiving a
2 signal from fill sensor 64, microcontroller 72 deactivates pump motor 83 and fan 74 and
3 activates alarm 95 to signal the user that canister 19 must be replaced.

4 Control system 70 includes switch 63 to prevent users from operating wound
5 closure apparatus 10 without a canister properly installed. If a canister is not properly
6 installed, switch 63 remains open and therefore outputs no signal to microcontroller 72.
7 If microcontroller 72 receives no signal from switch 63, indicating no canister within
8 chamber 18, it will not supply power to pump motor 83 even after a user has pressed
9 on/off button 78. Furthermore, microcontroller 72 activates alarm 95 to signal the user
10 that either a canister is not properly installed or is improperly installed within chamber
11 81. Microcontroller 72 operates pump motor 83 only if switch 63 is depressed to provide
12 a signal indicating the proper placement of a canister within chamber 18.

13 Control system 70 includes tilt sensor 82 to prevent operation of wound closure
14 apparatus 10 if it is tilted excessively. Excessive tilting of wound closure apparatus 10
15 during operating diminishes the efficiency of removal of wound fluids and, more
16 importantly, might result in either the contamination of vacuum pump 84 or the spilling
17 of wound fluids. Thus, if wound closure apparatus 10 tilts along any of its axes beyond a
18 predetermined angle (approximately 45° in this preferred embodiment), tilt sensor 82
19 outputs a signal to microcontroller 72. In response, microcontroller 72 deactivates pump
20 motor 83 and activates alarm 95 to signal the user of the excessive tilt situation. In this
21 preferred embodiment, tilt sensor 82 may be implemented with any standard mercury

1 switch. A predetermined delay (e.g. 30 seconds) may be incorporated in the circuitry so
2 that the tilt alarm does not operate immediately.

3 Although the invention has been described with reference to specific
4 embodiments, this description is not meant to be construed in a limited sense. Various
5 modifications of the disclosed embodiments, as well as alternative embodiments of the
6 inventions will become apparent to persons skilled in the art upon the reference to the
7 description of the invention. It is, therefore, contemplated that the appended claims will
8 cover such modifications that fall within the scope of the invention.